The Open University

Science Supplementary Material
S382 Astrophysics

S382

Introduction and Guide

READ THIS DOCUMENT FIRST!

Contents

Introduction

Welcome to S382 *Astrophysics* – we hope that you will enjoy the module. The purpose of this document is to summarize what S382 is about, to outline its overall structure, to point out some of the relationships between the various components, and to act as a source of information to which you may refer during your studies.

1 The structure and content of S382

S382 is a Level 3 module on astrophysics that builds on Level 2 astronomy, physics and mathematics; it comprises three parts. The first and last of these are based around conventional OU self-study textbooks, whilst the middle third is a group project concerned with astrophysical data analysis and uses various software tools for data processing and for communication within the group.

The first third of S382, **Stellar Evolution and Nucleosynthesis**, is based around a book with a simple story, following the cycle of stellar evolution while emphasizing the role of stellar nucleosynthesis throughout. The book begins by considering the properties of stars on the main sequence and then briefly surveys the role of gravitational contraction in driving stellar evolution. It then moves on to look in detail at the physics of nuclear fusion before following the evolution of stars from the main sequence to the giant branch. Later stages of stellar evolution are covered next, beginning with helium-burning stars before looking at the formation of white dwarfs and planetary nebulae and then further nuclear burning and neutron-capture reactions. The end-points in the evolution of high-mass stars – supernovae, neutron stars and black holes – are considered next, before completing the cycle of evolution with a look at how stars form from the collapsing gas clouds seeded by the nuclear-enriched produce of earlier generations of stars.

The middle third of S382, **Astrophysical Data Analysis**, is a practical component, but one which you study at home, linked via the Internet with a small group of (up to 10) students with whom you will work collaboratively on a project involving astrophysical data analysis and interpretation. You will acquire data either from the OU's robotic telescope (PIRATE) or from the online Sloan Digital Sky Survey (SDSS) archive. In the first case you will carry out a project based around photometric light curves of newly discovered variable stars, whilst in the second case you will carry out a project concerning optical spectroscopy of quasars. In either case, your group will acquire, analyse and interpret a unique dataset, before presenting your findings. You will record your individual project activities in a series of weekly Progress Reports, and will contribute to a final group wiki report. Although you will be invited to express a preference between the PIRATE and the SDSS version of the project, we *cannot* guarantee which of the two you will be allocated, due to the limitation in the number of students that can be accommodated by the former.

The final third of S382, **Transiting Exoplanets**, is based around a book that explores the physical properties of exoplanets. It focuses on transiting exoplanets as these are the planets for which both the mass and radius (hence density) may be measured and for which the atmospheric properties may be determined. The book begins by looking at what we might discover about the Solar System if we were observing it from a distance, before moving on to look at how transiting exoplanets are found and investigated. The details of the transit light curve are examined next, then a review of the transiting exoplanet population is presented. Further deductions that may be made using spectroscopy and photometry are covered next, including information that may be deduced about a planet's atmosphere and weather. Finally the book considers the topic of orbital dynamics and how precise measurements of planetary transits may enable other objects in the distant planetary system to be discovered. The book concludes with a consideration of what the future may hold and the prospects for discovering biomarkers (life signatures).

E-text The two printed books will also be accessible in e-text format on the S382 website. The e-text will be searchable, so you can find the references to any term of interest. We do not expect you to print out large sections of the books, though there may be occasions when printing a chapter to take to study on a beach, for example, is a better option than taking one of the books.

Worked examples and exercises The books contain many worked examples and exercises, and these should play an important part in your learning. The worked examples illustrate important skills, and should be studied where you meet them in the text. Tackling the exercises is also a vital part of the learning process, since this allows you to gauge your understanding of the text and prepare for assignments. We strongly recommend that you attempt each exercise as soon as you meet it in the text.

2 Learning outcomes

(NB The numbering of these learning outcomes either matches or complements that in the partner module, S383.)

S382 provides you with opportunities to develop and demonstrate the following learning outcomes.

Knowledge and understanding:

At a depth appropriate to Level 3 study, you should be able to demonstrate knowledge and understanding of:

Kn1 the terminology used to describe the properties and behaviour of extrasolar planets and isolated stars,
Kn2 basic concepts of hydrodynamics, thermodynamics, plasma physics, quantum physics, nuclear physics and particle physics that are of relevance to astrophysics,

S382 Stellar Evolution and Nucleosynthesis:
Kn3 the properties of stars at different stages of their evolution – how they form, what happens to them as they age, and what becomes of them when they die,
Kn4 the physical processes that sustain the energy output of stars during each stage of their evolution and drive the progression from one stage to the next,
Kn5 the relationship between different stages of stellar evolution and the production of the chemical elements,

S382 Astrophysical Data Analysis:
Kn6 the principles underlying the astronomical techniques used in the practical work that you carry out,
Kn7 the scientific background to the practical work that you carry out,

S382 Transiting Exoplanets:
Kn8 methods used in the detection and characterization of exoplanets, in particular the properties revealed by exoplanet transits,
Kn9 astrophysics of planets as revealed by the known population of transiting exoplanets,
Kn10 the scientific examination of the question 'is life unique to Earth?' in the context of exoplanet research.

Cognitive skills:

On completion of S382 you should be able to:

C1 manipulate numbers, algebraic symbols and mathematical functions in equations of relevance to astrophysics and cosmology,
C2 apply the techniques of differentiation and integration and manipulate differential equations which are of relevance to astrophysics and cosmology,
C3 derive and manipulate quantitative theoretical models of physical processes and use such models to make physical estimates,
C4 demonstrate the interplay between modelling and observation or experiment,
C5 critically evaluate arguments and data and formulate judgements in accordance with astrophysical and cosmological theories and concepts,
C6 pursue disciplined abstract reasoning.

Key skills:

On completion of S382 you should be able to:

Ky1 organize and clearly present relevant information in response to defined tasks, including the expression of mathematical and scientific concepts using clear, concise and correct scientific prose,
Ky2 learn from a variety of sources and media including material on the WWW and journal articles which are not specifically written for an undergraduate audience,
Ky3 evaluate and synthesize information from a variety of sources and media,
Ky4 work in small groups to collaboratively plan observations and analyse astronomical data.

Practical and/or professional skills:

On completion of S382 you should be able to:

P1 search for and download relevant information from the WWW,
P2 use computer software to analyse data, model physical processes and present the results appropriately,
P3 demonstrate the skills necessary for self-managed and lifelong learning in terms of working independently, time management and organization.

3 Components

In this section we discuss the various components that make up S382.

(a) The S382 website (accessible from your StudentHome page) is an important source of information and resources, which will be added to during the year. You should aim to check the website every few days for new items. The website will contain the following:

- Latest news about S382;
- Any important errata for the materials and assignments;
- Information about e-tutorial scheduling and topics;
- Access to the e-tutorials;
- The e-text versions of the printed books;
- The *Specimen Examination Paper* (and *Solutions*), *Equations booklet* and *Revision and Examination Guide*;
- The assignments;
- Access to the eTMA and iCMA systems;
- The *Glossary*;
- S382 forums;
- Additional resources to help your understanding, e.g. screencasts.

From time to time, we may add other items of interest such as:

- Links to external websites that provide useful or interesting information related to S382;
- News about developments in research in astrophysics.

(b) The *Study Planner* on the website outlines what you should be doing each week and should be the first place you look as you plan your studies. As well as indicating the relevant book chapters to read each week, it also describes various activities that are based on material on the DVD, or on resources you will access over the internet. These activities are designed to reinforce the information you have read in the books, and to help you develop some of the skills that are listed in the learning outcomes.

In the middle third of S382, concerning the group project, the web-based *Study Planner* contains detailed information about the activities which comprise the majority of your work during this part of the module.

The *Study Planner* also indicates when each assignment should be completed as you work through the module.

(c) The two books provide the vast majority of the study material for the first and final thirds of S382. They are divided into chapters, each of which is designed to occupy roughly a single study week. You should work through them in turn as you progress through S382, as indicated on the *Study Planner*. To help you keep track of the material you are learning and provide you with a concise list of the key information that you should remember, each chapter concludes with a summary consisting of a series of numbered points. These summaries list the bare bones of the material in the book and should highlight for you which parts are the most important to concentrate on.

(d) The middle third of S382, the data analysis group project, has no printed material – all the information you need for this part of the module will be found on the website. The majority of your work for the project will be based around a set of activities that you carry out with other members of your group of up to 10 students. Each study week has several activities for you to carry out and your weekly Progress Reports describing what you have done in response to each activity will contribute to the assessment for this part of S382.

(e) We have provided you with an online hyperlinked *Glossary* of 'bold terms' for S382. (This is actually a joint glossary covering both S382 and S383.) You can access the *Glossary* from the website.

(f) Accompanying the books and online material are a few DVD-based activities. These are interactive tutorials containing video, audio commentary and animation as well as a high degree of interactivity, to which you are referred, via the *Study Planner*, as you work through S382. A number of other software applications which may be of use to your studies (such as OpenOffice and Adobe Reader) are available to download from the online *Computing Guide* which you can access from StudentHome.

4 Tuition

Tuition on S382 is organized through a Physical Science Student Support Team which operates across Level 3 Physics and Astronomy modules. You will be assigned an S382 tutor, as well as a pathway tutor who has a responsibility for overseeing your progress through this module and beyond as you further your OU study. In addition, you may be contacted by, or contact in turn, various other members of the Physical Science Student Support Team who have responsibility for particular aspects of S382's presentation.

All tuition for this module is presented electronically using a web-based real-time collaboration system which gives access to online virtual meeting rooms. You can access tutorials, project meetings and lectures via the S382 website. To make best use of this system you should acquire a simple, inexpensive headset incorporating both headphones *and* a microphone. These are available from many online or high-street suppliers.

Throughout S382 we will hold a number of module-wide tutorials. These will be open to all S382 students, and the tutors will take turns to present them. A typical module-wide tutorial might include a lecture, and possibly the step-by-step solution of a relevant problem, followed by an opportunity for questions and discussion. Details of the timings of these will be posted on the website. With the permission of participants, these sessions will be recorded so you can view them at a later date if you are unable to attend. Your tutor will also provide a number of tutorials specifically for your tutorial group. These may also be recorded with the permission of the participants. These will help you to get to grips with aspects of S382 that you may find challenging or that need reinforcing. We may also organize occasional guest lectures presented by members of the OU academic staff, and open to all S382 students, which will serve as enrichment around the main topics.

Each tutorial group will be split into project groups for the middle third of the module. During the project, you can expect your tutor to work closely with your group to help you achieve the project's goals. Consequently there will be a number of scheduled project meetings during this time which will be led by your tutor. You may also be able to use your online meeting room to hold informal project group meetings of your own.

5 Assignments

In order to pass S382 you must achieve a score of at least 30% on at least 8 out of the 10 assignments *and* achieve a score of at least 40% on the combined examinable components. Your grade will be determined by your score on the combined examinable components.

The assignments are designed to provide you with regular, targeted feedback in order to help you learn and to assess your own progress towards meeting the learning outcomes. There are two sorts of assignments: interactive computer-marked assignments (iCMAs) and tutor-marked assignments (TMAs).

Each iCMA consists of a set of 5 computer-based questions which allow you several attempts to answer them. If you get an answer incorrect, you will be presented with instant advice and feedback enabling you to have another go. You may attempt each iCMA as many times as you wish, and your highest score will be recorded. Although you will be given a recommended submission date for each iCMA at the appropriate point in the module, in practice you will have until the end of the module to finally submit them. The precise final submission date for the iCMAs will be given on the *Study Planner*.

The TMAs require you to send written answers to your tutor in response to detailed questions and problems that address the various learning outcomes. Your tutor will send you targeted feedback and advice on your answers, indicating how well your answers met the intended learning outcomes, and how they might be improved, if appropriate. There are also downloadable screencasts which will be available after the assignment cut-off dates and are designed to give further guidance on answering these TMA questions. Each TMA has a fixed cut-off date about a fortnight after the relevant study period. Note that this is different from the situation with the iCMAs. Unless you have good reasons for an extension, and have the agreement of your tutor, you will not be able to submit TMAs after the cut-off date specified on the *Study Planner*.

You are normally expected to submit all your TMAs electronically, using the online eTMA system. You can submit a word-processed document, or a scanned version of a hand-written one; advice on how to produce an eTMA will be provided on the S382 website. The eTMA system allows for TMA submission directly to the University 24 hours a day, and either gives you confirmation that your eTMA has been submitted

successfully or, if there has been a problem, an error message informing you of the problem and what steps you should take to overcome it.

To submit your TMAs electronically you will need to:

1. Log on to StudentHome.
2. Click on the 'assessment' link under the relevant module on your StudentHome page.
3. Click on the 'submit' link alongside the TMA you want to submit and follow the onscreen instructions.

General information about policy and procedure can be found in the *Assessment Handbook* which you can access from your StudentHome page.

Under certain circumstances, you can ask your tutor whether paper submission of your TMA will be acceptable. These circumstances could be, for example, your experience that typesetting equations electronically, or incorporating scanned images in your electronic document, would take you an unacceptably long time; or it might be that your computer is temporarily out of use. **Please note that, before submitting a TMA on paper, you must contact your tutor and obtain his/her agreement.**

If your tutor agrees to you submitting by post, you should be sure to post your TMA in sufficient time to arrive by the cut-off date. Do not send it using recorded delivery or guaranteed delivery; this can cause problems for tutors who are not at home to receive it. Instead, send it by first class post and ask for a proof-of-posting certificate at the post office and be sure to keep a copy of the assignment. If, for any reason, you are unable to complete your TMA on time, you must contact your tutor before the cut-off date to discuss possible options. Under exceptional circumstances your tutor may allow an extension, but this will be of limited duration and your answers must be received before screencast solutions are made available on the S382 website. The procedure for late submission of assignments is given in your *Assessment Handbook*.

Each iCMA and TMA covers a different part of S382 as follows:

iCMA 51 relates to *Stellar Evolution and Nucleosynthesis*, Chapters 1–2.
TMA 01 relates to *Stellar Evolution and Nucleosynthesis*, Chapters 3–4.
TMA 02 relates to *Stellar Evolution and Nucleosynthesis*, Chapters 5–6.
iCMA 52 relates to *Stellar Evolution and Nucleosynthesis*, Chapters 7–8.
TMA 03 relates to *Astrophysical Data Analysis*.
iCMA 53 relates to *Astrophysical Data Analysis*.
iCMA 54 relates to *Transiting Exoplanets*, Chapters 1–2.
TMA 04 relates to *Transiting Exoplanets*, Chapters 3–4.
TMA 05 relates to *Transiting Exoplanets*, Chapters 5–6.
iCMA 55 relates to *Transiting Exoplanets*, Chapters 7–8.

In order to qualify for a grade, you must submit satisfactory answers to at least 8 of the 10 assignments and you are *strongly* encouraged to attempt them all. Satisfactory completion of an iCMA will be deemed to be a score of 30% or more. Since you can attempt each question several times before finally submitting your answers, this should not be too much of a hurdle. The TMAs will each be assessed against a small number of the learning outcomes. Satisfactory completion of a TMA is also deemed to be a score of 30% or more which demonstrates that you have achieved better than 'no evidence' against some of the learning outcomes that are being assessed in that piece of work. However, you should not treat the minimum score as your target but should aim for as high a mark as possible. We know there is a close correlation between performance in assignments (TMAs and iCMAs) and in the examinable assessment.

The practice you will obtain by attempting the assignments, and the detailed feedback you will receive on your answers, will all help to prepare you for the other parts of the assessment that *do* contribute to your overall grade. Moreover, *some* of the questions in the iCMAs and TMAs will re-appear, possibly in slightly different form, in the end-of-module examination.

Recent experience shows that increasing numbers of students are committing plagiarism in assignments, sometimes inadvertently. Plagiarism is using the work of other people to gain some form of benefit without formally acknowledging that the work came from someone else. For information and advice on what constitutes good academic practice (and hence how to avoid plagiarism) please go to the *Developing good academic practice* website at http://learn.open.ac.uk/site/dgap001/.

To check that students are working in a fair and academically appropriate manner, the Open University is currently using some text-comparison software to detect potential cases of plagiarism in work that is submitted for assessment. Details of how this is to be used in this module will be given on the S382 website.

6 Examinable assessment

There are two components to the examinable assessment of S382 which will determine your final grade.

The first of these examinable components (EC1) is a portfolio of work which describes how you carried out the group project in the middle third of S382 and what your group ultimately achieved. This portfolio will comprise two elements: the individual Progress Reports that you complete following each week's Activities, plus the collaborative group wiki that you produce by the end of it.

What is a wiki? A wiki is a website that can be edited easily by its users. Wikis enable group collaboration by providing users with both author and editor privileges. Participants work together to add, expand and change the content. Old versions of pages are never deleted and can be restored. The best known example is Wikipedia, the online encyclopedia which uses wikis to allow any user to create or edit an entry, thus taking advantage of the mass of knowledge distributed across the globe.

Your individual Progress Reports and group wiki must be submitted at the end of this study period, by the deadlines shown on the *Study Planner*. This means that you will have one-third of the examinable assessment under your belt before the end of the module! However, as this is an *examinable* component your marked work won't be returned to you and you won't get feedback on your performance until you have completed S382 and your overall score is released. Your marks for the Progress Reports and the wiki will be judged against the module learning outcomes and based on a combination of your individual performance in the project, and your contribution to the group work, as evidenced by the work which you and your group submit. The two components of the portfolio will carry an equal weighting and together will constitute one-third of the overall mark for S382.

The second examinable component (EC2) is a final examination that lasts three hours and assesses only the first and final thirds of S382. The paper consists of three parts. Part 1 carries 50% of the marks, and contains eight short questions, comprising four each on the first and final thirds of S382. You should attempt all the questions in this part of the exam. Parts 2 and 3 are worth 25% each and require you to answer one longer question from a choice of two in each part. Part 2 relates to the first third of S382 and Part 3 relates to the final third of S382. The exam as a whole will constitute two-thirds of the overall mark for the module.

You will also be provided with a *Specimen Examination Paper* (together with *Solutions*) to show you what to expect. It is worth noting that the *Specimen Examination Paper* includes an extensive *Equations booklet*, and that an identical booklet will be included in your final examination paper. Therefore, you do not have to remember any of the equations you meet in this module. Rather, you will have to recognize equations in order to know what they represent and you will have to understand what the various symbols stand for. You should also note that it is S382 policy to include in the examination a small number of questions which are based upon those in the assignments. Use of a **scientific calculator** is allowed in the examination, but the calculator must not be programmable and must not be able to store text.

Your S382 grade will be based on the sum of your scores from the two examinable components; you do not have to pass both components separately, all that matters is your overall score. If your overall examinable component score is not high enough to pass S382, you may be permitted to resit the exam or you may be offered a viva voce examination (depending on the circumstances), provided that you have satisfied the assignment (TMA and iCMA) thresholds. Note that although it may be possible to defer or resit the examination (EC2) it is not possible to defer or resubmit EC1.

In summary, to obtain a credit in S382, you must have demonstrated satisfactory engagement with the TMAs and iCMAs (as specified above) and you must pass the examinable assessment. The grade you obtain will then be determined solely by your EC1 and EC2 marks.

7 Astrophysical Data Analysis Project

At the start of S382 you will be invited to express a preference regarding which of the two projects (i.e. PIRATE or SDSS) that you wish to carry out. Details of how to register your preference will be provided via email and/or the S382 website.

Please note that there is a limit on the number of students that we can accommodate within the PIRATE project. Should more students express an interest in PIRATE than there are places available, then the places will be allocated randomly from those that have expressed an interest. If you do not express a preference regarding project choice, you will be allocated to either the PIRATE or SDSS projects *after* the students who have expressed a preference have been allocated to projects.

The nature of the PIRATE project dictates that you will need to be available for at least some part of your group's scheduled observing allocation on the Open University's robotic telescope. There will be approximately 10 hours of darkness per observing night with each group deciding for themselves a strategy to make best use of this time allocation. As the observatory is located in Mallorca, the observing nights coincide roughly with UK nights. As a result, if you have personal commitments that impact on your ability to play a role in the observing element of the PIRATE project, then you should think carefully before expressing an interest in this project. The SDSS project offers somewhat more flexibility than PIRATE in terms of the times when you are required to engage with activities since there will be no allocation of telescope time.

You should also note that due to the large volume of data that you will be downloading and working with, you will not be able to do the PIRATE project if you do not have access to a broadband internet connection. The SDSS project may also present some difficulties without broadband, but should be possible to complete in collaboration with other members of your group.

Once the allocations have taken place you will be informed, via email, of the following:

- The project (i.e. PIRATE or SDSS) that you will be required to work on.
- The name of the student group to which you have been allocated.

The project itself will begin in **Study Week 11**.

8 The S382 Production Team

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Feedback to the S382 Team We welcome your comments about S382, whether positive or negative. In particular, although we have a fairly robust system of checking and quality assurance for the materials, some errors may slip through. So if you notice any mistakes in the module (for example, misprints that make nonsense of an important sentence or an assignment question) which you think need correcting as soon as possible, please contact the S382 Curriculum Manager. Don't assume someone else has done so.

9 Whom should you contact if you have queries or problems?

The table below gives a list of useful contacts if you have difficulties or queries relating to your studies.

Your StudentHome page at **http://www.open.ac.uk/students** also provides many points of contact.

If you have queries or problems relating to:	Whom to contact:
Academic aspects of S382; clarification and/or help with the module materials; queries about TMAs or iCMAs.	Your tutor. Contact details are on StudentHome.
Non-receipt of a marked TMA.	First contact your tutor, then if necessary the Physical Science Student Support Team Email: physical-science-support@open.ac.uk Telephone: +44 (0)845 366 0474 Otherwise, if you need to contact the central OU: Telephone: +44 (0)1908 653051 Write to: Assignment Handling Office The Open University, PO Box 722 Milton Keynes MK7 6ZT
Problems contacting your tutor or anything related to tutor support.	The Physical Science Student Support Team Email: physical-science-support@open.ac.uk Telephone: +44 (0)845 366 0474
Information about online tutorial dates and times.	The S382 website or the Physical Science Student Support Team Email: physical-science-support@open.ac.uk Telephone: +44 (0)845 366 0474
Non-receipt of, incomplete, or damaged materials, including CD-ROMS/DVDs; requests for replacement materials if you lose or damage items.	In StudentHome click on 'materials despatch' Telephone: +44 (0)1908 332633
Queries about computer hardware and difficulties with module software	In StudentHome click on the 'Help' tab and 'Computing help' Telephone: +44 (0)1908 653972
Obtaining copies of published articles, literature searches, searching the internet and using other Library resources.	In StudentHome go to the 'Services' section and click on 'Library services' Telephone: +44 (0)1908 659001 Email: library-help@open.ac.uk Website: www.open.ac.uk/library Write to: Library Services The Open University Walton Hall Milton Keynes MK7 6AA

If you have queries or problems relating to:	Whom to contact:
Advice for students with disabilities.	In StudentHome go to the 'Services' section and click on 'Services for disabled students' Telephone: +44 (0)1908 653745 Textphone: +44 (0)1908 655978 Email: Disabled-student-resources@open.ac.uk Website: www.open.ac.uk/disability Write to: The Learner Support Team at your Regional Centre or Disabled Students Resource Team The Open University Hammerwood Gate Kents Hill Milton Keynes MK7 6BY
Module registration.	In StudentHome click on the 'Help' tab Telephone: +44 (0)845 300 6090 Email: general-enquiries@open.ac.uk Write to: The Learner Support Team at your Regional Centre or Student Registration and Enquiry Service The Open University PO Box 197 Milton Keynes MK7 6BJ
Study choice and degree pathway planning.	The Physical Science Student Support Team Telephone: +44 (0)845 366 0474 Email: physical-science-support@open.ac.uk
All other queries including: study issues, withdrawal from the module, change of name or address.	The Physical Science Student Support Team Telephone: +44 (0)845 366 0474 Email: physical-science-support@open.ac.uk
Comments on the module itself or on the assignments (e.g. suspected errors, suggestions for improvements).	The S382 Curriculum Manager Department of Physics and Astronomy The Open University Milton Keynes MK7 6AA Email: OU-Science@open.ac.uk (Please quote the module code, S382, in the subject field.)

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